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During thee past four years, extensive analyses of the convective and frontal structure within rapidly deepening cyclones over the Atlantic Ocean has been documented. Intense warm fronts that have undergone a scale contraction were observed for the first time. In addition, mesoscale vortices, approximately 25-40 km wide, were shown to develop along these warm fronts. When these vortices come into a proper phasing with a baroclinic wave aloft, rapid deepening of the central low pressure appears to occur. The kinematic and thermodynamic structure of these fronts and vortices have been published in the literature.

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February 21, 1997

Dr. Robert F. Abbey, Jr.
Program Manager for Marine Meteorology
Dept. of the Navy
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800 N. Quincy St.
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Dear Bob,

Enclosed is a final report for the grant from the Office of Naval Research that recently ended (#N00014-91-J-1068). An overview of the research objectives and a listing of the publications over the last 4 years are included. Thank you for your support over the years.

Sincerely,

Roger M. Wakimoto
Professor of Meteorology

Enclosure

Mesoscale Studies of Explosive Cyclogenesis

In recent years the midlatitude, over ocean winter storm than can explosively develop has gained a great deal of interest owing to its unpredictability and resultant devastating effect of commercial shipping and naval operations. In an attempt to understand the mechanisms that cause this large deepening rate in a relatively short period of time (10 mb/6 hr), ERICA (Experiment on Rapidly Intensifying Cyclones over the Atlantic) was organized for the winter 1988/1989 season.

The most important research data platforms deployed during ERICA were the NOAA P-3 aircraft equipped with Doppler radar. It was recognized early in the program that airborne dual-Doppler analyses would be important to identify the location of the convection within these cyclones and to provide detailed kinematic motion in select portions of the storm. The former objective was to identify the areas of latent heat release which is critical to understand how the cyclone is maintained. The latter was important to complete the three-dimensional wind structure in more detail than could be provided by in-situ measurements recorded by the P-3 aircraft.

Over the past four years, extensive analyses of the IOP #4 and 5 storms have been performed. Perhaps, the most important result of these studies is the documentation of mesoscale vortices, approximately 25-40 km wide, developing along intense warm fronts that have undergone a scale contraction. When these vortices come into a proper phasing with a baroclinic wave aloft, rapid deepening of the central low pressure appears to occur. This details of this process have not been documented before in the literature.

One of the limitations of Doppler radar analysis is that it only reveals the kinematic structure of the phenomenon under investigation. Recent techniques have

been developed that allow for a thermodynamic retrieval (from the dual-Doppler wind field) of the perturbation pressure and buoyancy fields using the anelastic momentum equations. Such information is critical to determine when comparing observations with the numerical simulations of extratropical cyclones.

The following papers have been published that address the above objectives and acknowledge funding from the Office of Naval Research -

Results from based on Support from the Office of Naval During the Past 4 Years

1. Wakimoto, R.M., 1993: Mesoscale analysis of convective phenomena. *International Workshop on Mesoscale Meteor. and TAMEX Program Review*, Taipei, 84-93. **INVITED TALK.**

2. Wakimoto, R.M., and J.K. Lew, 1993: Observations of a Florida waterspout during CaPE. *Weather and Forecasting*, **8**, 412-423.

3. Wakimoto, R.M., and N.T. Atkins, 1993: Airborne Doppler analyses of an intense extratropical cyclone during ERICA., *Preprints, 26th Conf. on Radar Meteor.*, Norman, Amer. Meteor. Soc., 282-284.

4. Wakimoto, R.M., and P.G. Black, 1993: Damage survey of Hurricane Andrew and its relationship to the radar-detected eyewall. *Preprints, 20th Conf. on Hurricanes and Tropical Meteor.*, San Antonio, Amer. Meteor. Soc., 54-57.

5. Blier, W., and R.M. Wakimoto, 1994: Synoptic and mesoscale analysis of the early evolution of the ERICA IOP 5 explosive oceanic cyclone. Proceedings, *The Life Cycles of Extratropical Cyclones, Vol. III*, Bergen, Norway, 25-30.

6. Paldor, N., C.-H. Liu, M. Ghil, and R.M. Wakimoto, 1994: A new frontal instability: Theory and ERICA observations. *J. Atmos. Sci.*, **22**, 3227-3237.

7. Wakimoto, R.M., and P.G. Black, 1994: Damage survey of Hurricane Andrew and its relationship to the eyewall. *Bull. Amer. Meteor. Soc.*, **75**, 189-200.

8. Wakimoto, R.M., N.T. Atkins, and C.-H. Liu, 1994: Airborne Doppler analysis of the mesoscale circulation and frontal structure of an explosive oceanic cyclone during ERICA IOP 5. Proceeding, *The Life Cycles of Extratropical Cyclones, Vol. III*, Bergen, Norway, 236-241.

9. Blier, W., and R.M. Wakimoto, 1995: Observations of the early evolution of an explosive oceanic cyclone during ERICA IOP 5. Part I: Synoptic overview and meso-a-scale structure. *Mon. Wea. Rev.*, **123**, 1288-1310.

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11. Liu, C.-H., R.M. Wakimoto, N.T. Atkins, and F. Roux, 1995: Dynamic and thermodynamic retrievals of airborne dual-Doppler radar analyses for the ERICA IOP 4 and 5 storms. *Preprints, 27th Conference on Radar Meteorology,* Vail, Amer. Meteor. Soc., 808-810.

12. Liu, C.-H., 1996: Analysis of mesoscale circulations within explosively-deepening marine cyclones - ERICA Observations. Ph.D. Dissertation, University of California, Los Angeles, 149 pp.

13. Liu, C.-H., R.M. Wakimoto, and F. Roux, 1997: Observations of mesoscale circulations within extratropical cyclones over the North Atlantic Ocean during ERICA. *Mon. Wea. Rev.*, **125**, 341-364.